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Decision tool for climate disasters and infectious disease at sub-national level in India: Ensuring a paradigm shift in health planning from prevalence to vulnerability

Nitish Dogra[a,*], Varun Kakde[b], Pawan Taneja[c]

[a] International Institute of Health Management Research, Delhi, India
[b] Independent Public Health Consultant, Delhi, India
[c] Indian Institute of Public Administration, Delhi, India

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ABSTRACT

Climate change is considered as a distal determinant of public health which is increasing in importance. India, as an example, has a national action plan for climate change and human health. Sub-national (State) plans for climate change also exist, taking into account the health sector. The State of Bihar was selected for assessment because of its vulnerability (a function of exposure, sensitivity and adaptive capacity). A vulnerability framework was constructed by discussions with national and local-level specialists followed by weightage given by working in the field of climate and health with international exposure. A total of 15 districts were at a high risk of floods and these were considered for detailed analysis using the methodology for human development index as well as other examples in the field of environment. Climate health vulnerability index score were correlated with actual prevalence of flood mortality data of these 15 districts in year 2016. It was found that climate health vulnerability and flood mortality had negative low correlation of -0.25. In contrast for vector-borne diseases (VBD), both pre-flood and post-flood, the morbidity data had a correlation of 0.24 and 0.11 respectively. Possible reasons for a negative correlation for mortality could involve better preparedness by disaster district authorities. However, outbreak control is within the ambit of the health sector where a possible reason for decreased correlation coefficient in the post-flood period could be due to the impact on health facilities itself, thus leading to reduced reporting.

1. Introduction

Climate change is considered as a distal determinant of public health, which is increasing in importance. An extensive compilation related to the health impacts of climate change in India has shown that a number of different outcomes are affected ranging from infectious diseases such as vector borne diseases and water borne diseases, heat and cold wave consequences, disaster related injury and deaths as well as respiratory diseases. Besides the health-related consequences, there are also economic impacts due to multiple factors including the threat to livelihood (Dogra and Srivastava, 2012). These inter-relationships via direct and indirect pathways are depicted in the figure shown below.

India has ratified the Paris Agreement on Climate Change ("India ratifies the Paris Agreement on Climate Change, 2016). A national action plan for climate change and human health has also been drawn up (Ministry of Health and Family Welfare Government of India, 2016). In addition, there are various sub-national or state action plans for climate change, such as the one for Bihar state (Government of Bihar, 2015). These include sections on health (Fig. 1).

The State of Bihar where the study was carried out has several risk factors from the perspective of climate and health vulnerability. These include a high degree of exposure to climate extremes such as floods, high population density, poverty, genderand governance related risk factors (see Fig. 2 and Table 1).

The disaster scenario in Bihar is also expected to worsen with climate change. Bihar is characterized by multi-hazard natural disasters including winds, cyclones, floods and earthquakes (Singh et al., 2014). Bihar as a state is particularly vulnerable to floods, with 15 out of 37 districts being in the worst affected category. This is depicted in the map shown ahead.

* Corresponding author.
E-mail address: drnitishdogra@gmail.com (N. Dogra).

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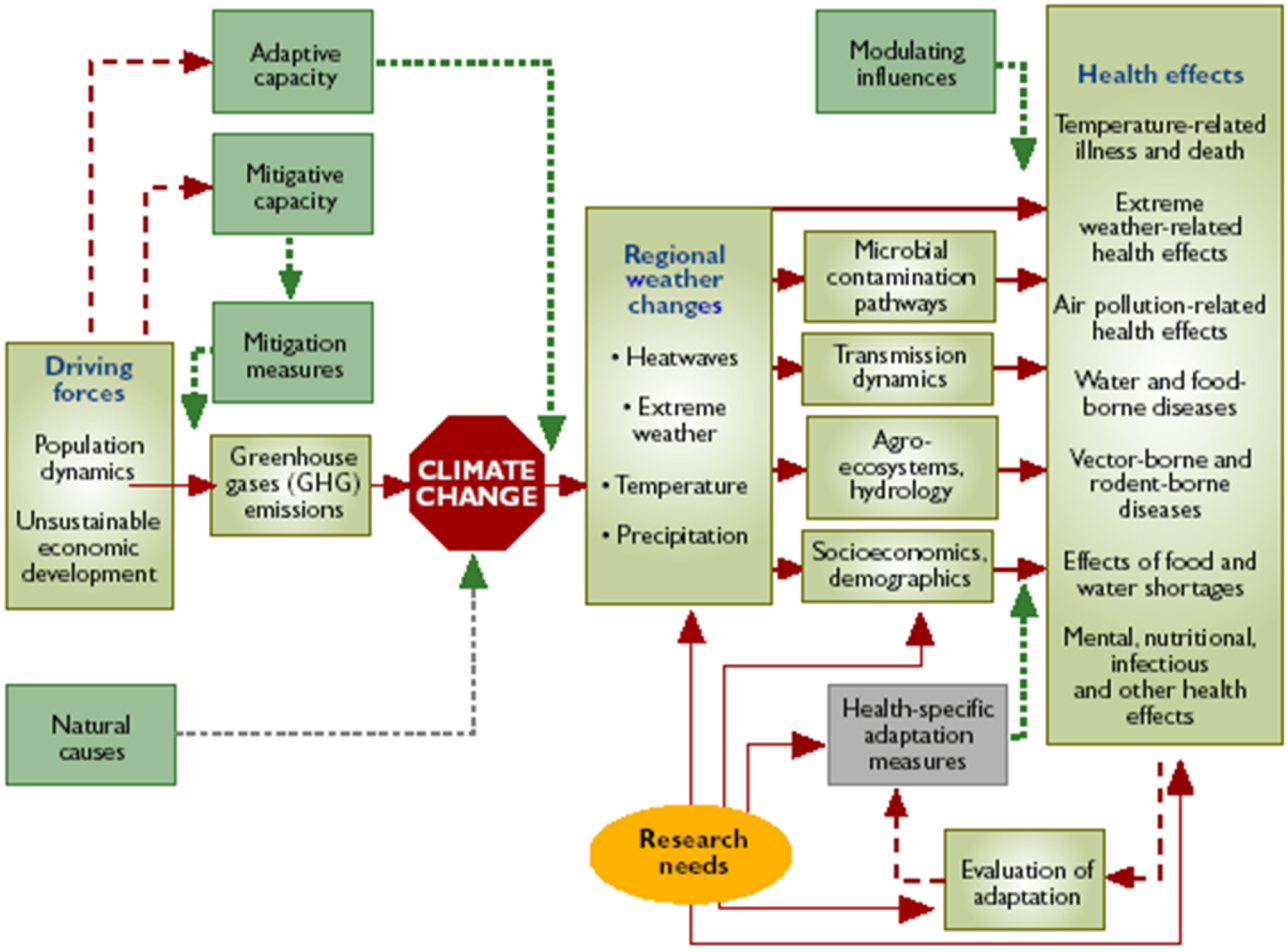


Fig. 1. Relationship Between Climate Change and Health.
(Source: World Health Organisation).

1.1. Rationale

Vulnerability is considered as a function of exposure, sensitivity and adaptive capacity according to the IPCC (Cardona et al., 2012). This construct has been utilized for devising a climate vulnerability index.

Health and nutrition indicators in Bihar lag behind other states in India. Although the mortality and morbidity estimates provide some insight into the state of the health system, it does not reflect a comprehensive overview. Composite vulnerability indices incorporating gender as well as socio-economic indicators and environmental hazards such as floods, provide an overall vulnerability indicator for the health sector. Examples of these indices exist within the health sector and outside. These are described in the Indian context in the box item below:

Box 1 Mapping Climate Vulnerability for Health in India

Climate vulnerability indices outside the health sector have been used on several occasions such as for agriculture (O'Brien et al., 2004). Within the health sector this approach has been utilized in Pakistan (Malik et al., 2012) for the health sector and London, UK (Wolf and McGregor, 2013) for heat

A prototype of the Cyclone Vulnerability Index for the Health Sector was developed for 31 districts in the east coast of India in relation to high risk for cyclone damage. With that exposure factor in common, a simple vulnerability index was compiled using population density as a sensitivity parameter and human development index as well as public health preparedness as adaptive capacity indicators (Shukla and Dogra, 2012).

A pilot tool has also been developed at the State Level as depicted below for malaria in the state of Haryana in north India (Fig. 3). The final tool that has been developed takes into account malaria, diarrhoea and heat stress (Dogra et al., 2013). More recently a national heat index for health has also been developed (Azhar et al., 2017).

1.2. Objective

The aim of the present study is to determine the correlation of a flood vulnerability index (as a prospective decision tool) with mortality and vector-borne disease (VBD) morbidity.

2. Methodology

2.1. Universe

It consists of the most vulnerable flood prone districts in the State of Bihar. These comprise of the following:

1 East Champaran
2 Muzzafarpur
3 Vaishali

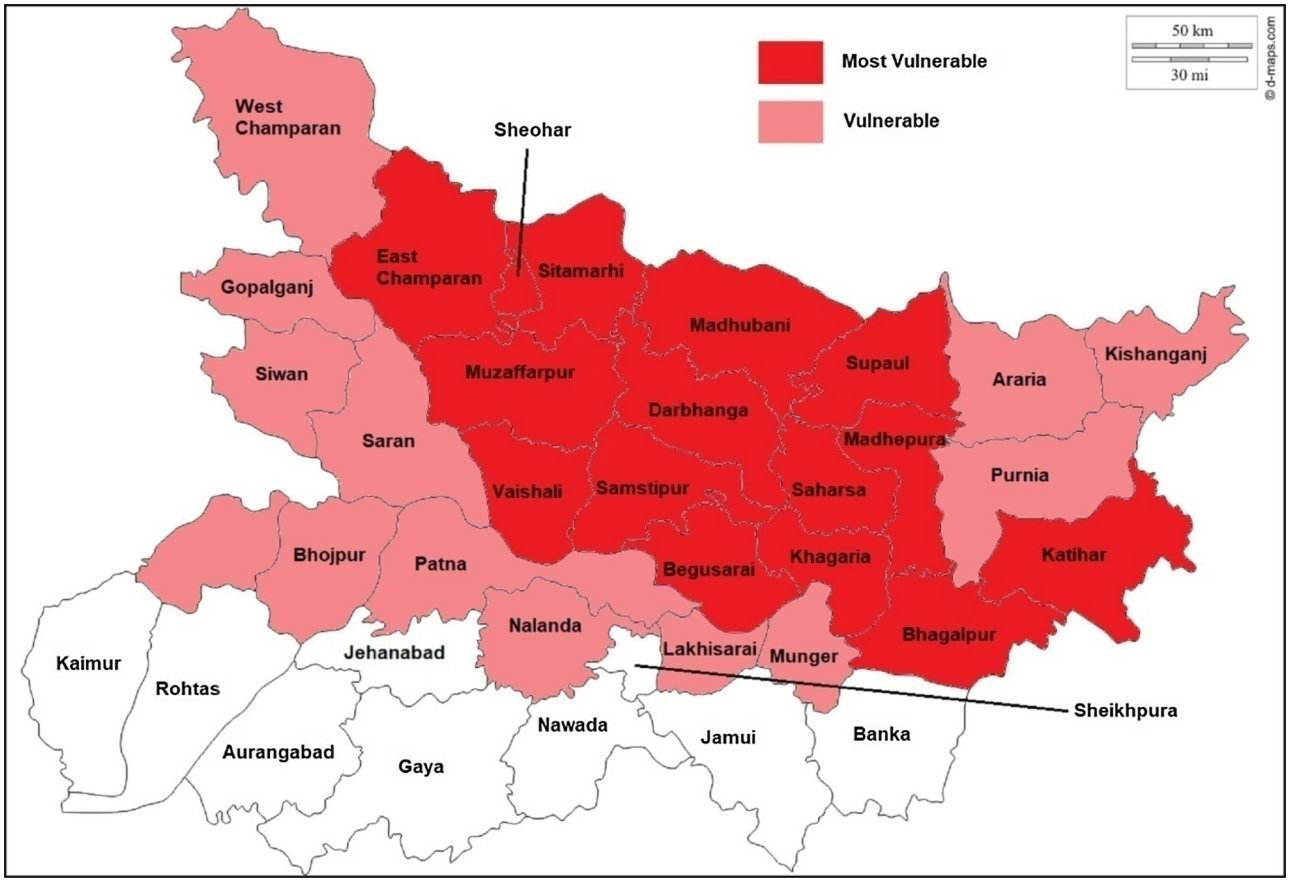


Fig. 2. Map of Flood Prone Areas in Bihar.
(Source: Government of Bihar).

Table 1
Select Development Indicators for Bihar.

No.	Indicator	Bihar	India
1	Proportion below poverty line (Planning Commission, 2009)	53.5	29.8
2	Sex Ratio (Census 2011)	916	940
3	Female Literacy Rate (%) (Census 2011)	53.3	65.5
4	Maternal Mortality Ratio (SRS 2010-12)	219	178
5	Total Fertility Rate (SRS 2012)	3.5	2.4
6	Prevalence of Underweight Children under 5 years of age (%) (India State Hunger Index 2009, IFPRI[a])	56.1	42.5
7	Number of rural households out of 1000 receiving daily water supply (NSSO, 2013[b])	515	753
8	Number of households without latrine facilities (NSSO, 2013)	728	594
9	Road density in km/1000 population in 2008 (Ministry of Statistics and Programme Implementation)	1.28	2.79

[a] International Food Policy Research Institute (IFPRI).
[b] National Sample Survey Office (NSSO).

4 Sheohar
5 Sitamarhi
6 Madhubani
7 Darbhanga
8 Samastipur
9 Supaul
10 Madhepura
11 Saharsa
12 Khagania
13 Begusarai
14 Katihar
15 Bhagalpur

2.2. Data sources

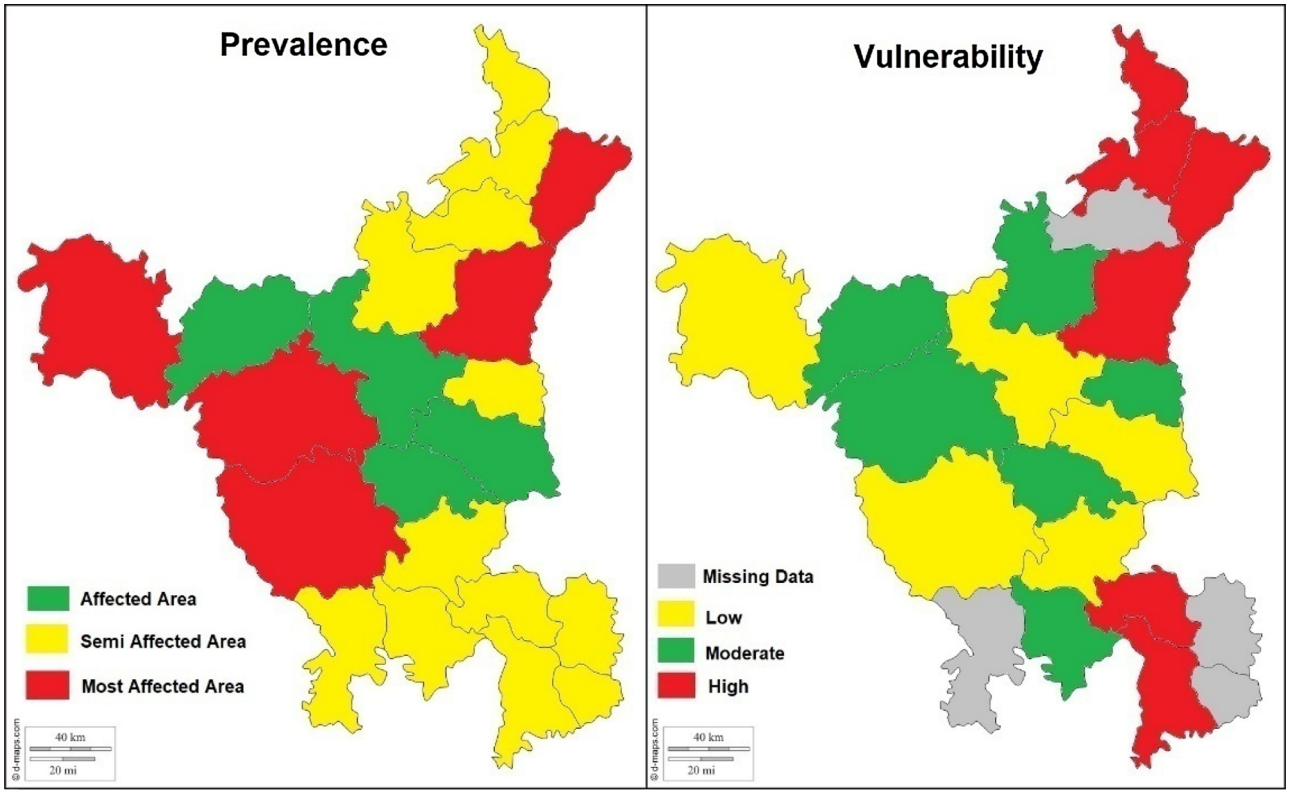
The study is primarily based on secondary data sources. For the purpose of this study, we used districts as the unit for our analysis as districts are appropriate for planning purposes, and are the smallest unit for which we could get reliable data from multiple sources. Data sources include the Census of India 2011; District Level Household Survey (DLHS) – 3 data; Sixth Economic Census, 2013; Flood Mortality data from Bihar Disaster Management Authority Portal; Integrated Disease Surveillance Programme (IDSP) Monthly Media Report on Vector Borne Diseases; State Health Society Bihar 2014 data on Prevalence of Under 5 Mortality and Malnourishment; Bihar Flood Management Information System for Early Warning System; Bihar Statistical Handbook, 2010 etc. Details of sources of various variables and their descriptive statistics like mean, maximum, minimum, and standard deviation were calculated for each of the district using SPSS software is shown in Table 2.

2.3. Choice of variables for vulnerability index

The vulnerability index was carried out as a prioritization exercise on the basis of secondary data obtained from above mentioned sources. The basis for the vulnerability index is the equation given below:

Vulnerability = f exposure, sensitivity and adaptive capacity

We have primarily used the conceptual framework developed in our previous work on assessment of the vulnerability of the districts in Haryana state for malaria, diarrhoea and heat stress (Dogra et al.,



a: Prevalence of malaria in Haryana districts (Source: Haryana State Action Plan for Climate Change)

b: Vulnerability of Haryana districts to Malaria (Source: International Institute of Health Management Research, 2013)

Fig. 3. Pilot Tool for Climate Vulnerability to Malaria at the Haryana State Level in India. a *Prevalence of malaria in Haryana districts* (Source: Haryana State Action Plan for Climate Change). b *Vulnerability of Haryana districts to Malaria*.
(Source: International Institute of Health Management Research, 2013).

2013b). Indicators for exposure, sensitivity and adaptive capacity from that study were updated on the basis on the new literature developments (World Health Organization, 2013; Wolf and McGregor, 2013; Bao et al., 2015; Azhar et al., 2017), and some of the indicators which were of duplicative nature representing similar constructs were removed. As in previous studies, shortlisted indicators are represented from across the demographic, social, economic, health, and environmental domains (Yusuf and Francisco, 2009); O'Brien et al., 2004; Khan and Salman, 2012; World Health Organization, 2013; Dogra et al., 2013a).

In this study, exposure across the most vulnerable flood affected districts was assumed to be the same; therefore the exposure category was not taken into account. We used coping capacity[1] instead of adaptive capacity in our framework, as this study was concerned with the current climatic condition. For finalization of indicators and respective weightage for each indicator a stakeholder group was formulated. As suggested in the World Health Organisation guide for Vulnerability and Adaptation (2013) the stakeholder group consisted of specialists[2] from different domains. In this study, the stakeholder group consisted of specialists from the field of disaster, gender, nutrition, economics, water and sanitation, public policy & administration as well as public health. On the basis of current literature review and availability of data specific to the State of Bihar for sensitivity and coping capacity, the stakeholder group finalized 16 specific indicators as compared to fewer indicators in the previous study (Dogra et al., 2013a). Stakeholders grouped sensitivity indicators into two categories i.e. Health and Social; Economic; Demographic indicators and coping capacity indicators in to 3 categories, that is,. Health; Social, Economic, Demographic; and Disaster indicators. After finalization of indicators, independent experts were blindly asked to give weightage to each indicator without informing the other. The weightages obtained were averaged and focussed round table discussions of stakeholders was organised to agree on the final weightage. After the discussion, experts once again gave their weighted scores and average of these scores was considered as final weights. Experts decided to give about 37% weightage to socio-demographic and health factors each, whereas disaster related factors were accorded 26% weightage (See Fig. 4). The indicators finalized with respective weightage is shown in Fig. 4.

2.4. Data analysis

In order to ensure comparability of the different indicators, each of them was normalized on a 0–1 scale for the 15 most vulnerable flood affected districts.

The formula of normalization is as follows:

$$\frac{Z_i = X_i - X_{\min}}{X_{\max}}$$

Where,

[1] Coping capacity reflects the ability of the health system and the community to adjust to the present climatic conditions.

[2] Each member in the stakeholder group was a specialist with a Ph.D. or a master degree in their respective field with minimum of 10 years of core experience in the domain area. The three independent experts who were involved in assigning weights had a combined experience of over 80 years related to climate change and disasters. Two of the three experts were associated with the Intergovernmental Panel on Climate Change (IPCC).

Table 2
Indicators with Data Sources and Key Statistics.

Sr. No.	Category	Source	Indicator	Mean	Standard Deviation	Min	Max
1	Socio-demographic	Census of India, 2011	Area (in sq. km)	2309	815.51	349	3501
2	Socio-demographic	Census of India, 2011	Population	3116068	1238363.94	656246	4801062
3	Socio-demographic	Census of India, 2011	Family Size	5	0.26	4.41	5.52
4	Socio-demographic	Census of India, 2011	Households	621243	249946.4	148889	984303
6	Socio-demographic	Census of India, 2011	% Population of Children (0-6 years)	18.92	1.12	17.22	20.45
7	Socio-demographic	Census of India, 2011	% Population of Women	47.48	0.39	46.81	48.17
8	Socio-demographic	Census of India, 2011	% Population of Elderly - 60+ Years	7.21	0.76	5.88	8.51
9	Socio-demographic	Census of India, 2011	Population Density	1374.43	288.99	919.21	1880.36
10	Socio-demographic	Economic Survey 2016, GoBihar	Per Capita Gross District Domestic Product (in INR)	10,470.67	3118.87	6209	18447
11	Health	State Health Society Bihar, 2014	Prevalence of Underweight	56.26	5.56	48.5	71.4
12	Health	State Health Society Bihar, 2014	Under 5 Mortality	84.33	12.75	65	106
13	Health	Census of India, 2011	No. of HH having Toilets within the premises	136277	68137.88	30398	256532
14	Health	Census of India, 2011	HH using a Public latrine	7142	3017.69	1865	11550
15	Health	Census of India, 2011	% HH - Open Defecation	78.46	6.44	66.28	89.17
16	Socio-demographic	Census of India, 2011	% Female Literacy to the Total Female Population	38.27	5.57	29.39	46.91
17	Health	State Health Society Bihar, 2014	PHC Medical Officers	14.62	4.61	7	21
18	Health	State Health Society Bihar, 2014	AYUS Medical Officers	6.13	3.27	1	10
19	Health	State Health Society Bihar, 2014	Total Government Doctors	154.47	59.85	61	255
20	Health	State Health Society Bihar, 2014	Doctors per 1 lakh Population	5.2	1.31	3.8	9.3
21	Health	ICDS, Government of Bihar	CDPOs	15.87	5.57	5	28
22	Health	ICDS, Government of Bihar	CDPO per 1 lakh Population	0.53	0.1	0.35	0.76
23	Health	PIP 2011-12, State Health Society Bihar	Functional PHCs	38.07	17.04	7	76
24	Health	PIP 2011-12, State Health Society Bihar	Functional PHC per 30,000 population	0.37	0.08	0.29	0.52
25	Health	ICDS, Government of Bihar	AWCs	2433.27	1003.53	513	3896
26	Health	ICDS, Government of Bihar	AWC per 1000 population	0.78	0.02	0.73	0.82
27	Disaster	QMRT Programme, AIIMS, Batch 1 to 5, 2014	Quick Medical Response Trained staff (Medical)	4.93	1.1	3	7
28	Disaster	Bihar Statistical Handbook, 2010	Roads	449.58	188.57	68.64	778.72
29	Disaster	Bihar Statistical Handbook, 2010	Road Density	19.46	4.42	14.98	32.11
30	Disaster	Census of India, 2011	HHs Receiving Safe Drinking Water	29411.27	20287.01	1708	60781
31	Health	Disaster Management Department, Government of Bihar	Flood Mortality 2016	14.23	6.41	3	23
32	Health	Integrated Disease Surveillance Programme	No. of VBDs_Pre-Flood 2016	67.31	96.2	0	266
33	Health	Integrated Disease Surveillance Programme	No. of VBDs_Flood 2016	87.85	140.33	0	404
34	Health	Integrated Disease Surveillance Programme	No. of VBDs_Post-Flood 2016	151.38	190.78	0	532
35	Disaster	Flood Management Information System, Bihar	Early Warning System				

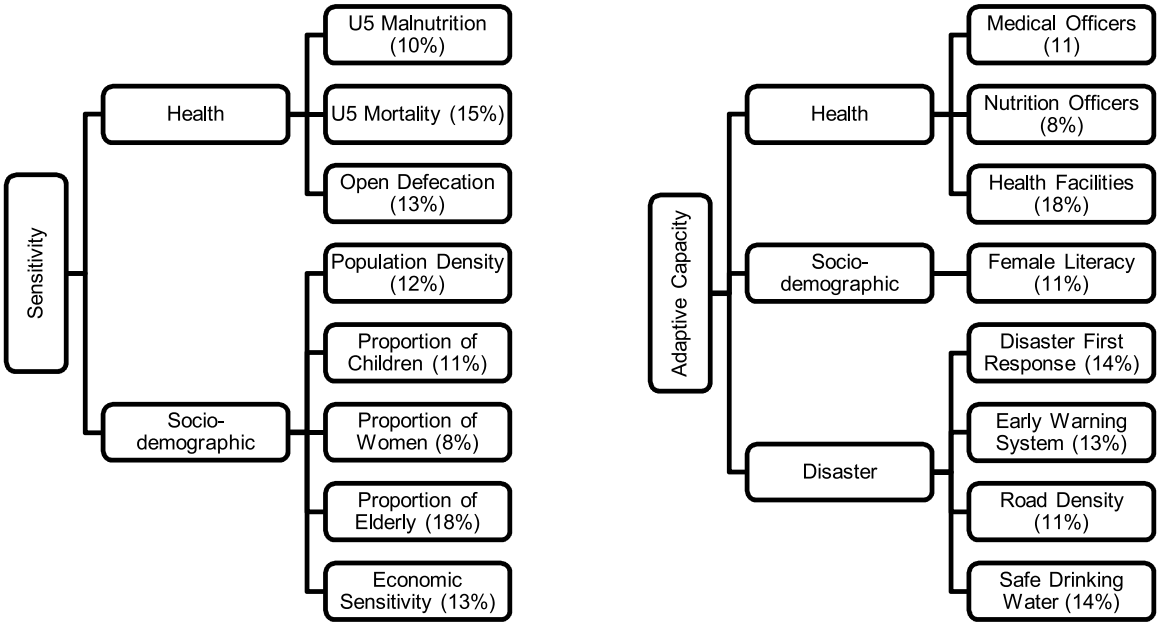


Fig. 4. Framework for Vulnerability Assessment.

- Zi is the standardized unit of district 'i'
- Xi is the unstandardized unit of an indicator value for district 'i'
- X_{max} is the maximum value of the indicator value over all the districts
- X_{min} is the minimum value of the indicator value over all the districts

- For indirect relationship like in adaptive capacity parameter, we will be taking the corresponding complementary values.

After normalization, the standardised score was calculated by using the above formula. The scores obtained were multiplied with respective to agreed weights. This resulted in overall weighted average scores from 0 to 1 for sensitivity and coping capacity. These scores were overlaid on the districts map of the State of Bihar. From the exposure; sensitivity and coping capacity, overall vulnerability scores were calculated. For the purpose of easy understanding, these scores were multiplied by 200. The scores obtained were ranked from 1 to 15, with 1 being the highest and 15 being the lowest. These flood vulnerability score with respect to health were divided into three categories, namely high, medium and low vulnerability.

Score	Level of Vulnerability
Above 120 points	Highly Vulnerable
Between 100 to 120 Points	Medium Vulnerable
Less than 100 Points	Low Vulnerable

The climate health vulnerability index scores was correlated with the actual prevalence of flood mortality data of these 15 districts in year 2016. The 15 districts considered as high exposure for floods (See Fig. 2) as per disaster management action plan were also overlaid with climate sensitivity map[3] and coping capacity map.[4] The flood vulnerability map with respect to health was mapped for the 15 districts with high, medium and low vulnerability categorisation.

3. Results

Out of 15 districts which were considered as most vulnerable for floods (See Fig. 2) as per disaster management action plan, four districts naming Madhepura, Sitamarhi, Sheohar and Muzzafarpur are found to be most vulnerable on the basis of climate health vulnerability (See Table 3 and Fig. 5). On the other hand districts like Bhagalpur and Begusarai were found to be least vulnerable mainly due to better coping capacity mechanism, i.e. presence of a large number of medical facilities. Climate health vulnerability index scores were correlated with the actual prevalence of flood mortality data of these 15 districts in the year 2016. It was found that climate health vulnerability and flood mortality had a negative low correlation as the correlation score is -0.25 (See Fig. 6 and Table 4). In contrast, for vector-borne diseases (VBDs) both pre-flood and post-flood, the morbidity data had a correlation of 0.24 and 0.11 respectively. This argument gets further strengthened when malaria morbidity data related to VBDs in the year 2016 for pre-flood and post flood period was correlated with climate health vulnerability index (See Fig. 7 and Table 5). As the correlation between VBDs in pre-flood and post flood period is positive, it is lower in degree. Correlation value in the pre-flood period is 0.24 and 0.11 in post flood period.

4. Discussion

The relatively recent introduction of climate vulnerability indices as a decision-making tool has the potential to bring about a paradigm shift in the approach to health planning in relation to climate-sensitive diseases. Specifically, the approach helps in capturing the true impact of a disease on society rather than disease prevalence based on the small fraction of cases reporting to the public health system. It helps policy planners and programme managers in judicious resource allocation in the health field and other sectors such as water, sanitation and food security. As an example, the Government of India in conjunction with the German Government has utilized these strategies in several states of India from the sub-national (state) to local level (GIZ, 2014). The maps are useful communication tools for varied stakeholders including the scientific community, lay persons and the press (WHO-WMO Joint Office for Climate and Health, 2016).

Within the State of Bihar similar indices have been developed for other conditions. An early example is at the district level for the parasitic disease Kala-Azar (visceral leishmaniasis) (Bhunia et al., 2012). The disease is endemic in several districts of the state. Although this example does not follow the IPCC framework but incorporates several of the indicators. In contrast, more recently an elaborate exercise has been conducted for the country for mapping heat vulnerability in relation to health. This is also being utilized for the State of Bihar for Disaster Risk Reduction planning (Government of Bihar, 2016)

Floods have multiple impacts on health, both direct in the form of deaths and injuries and indirect impacts such as infectious diseases and mental health (Few et al., 2004). In the Indian context, snakebites are also an important cause of morbidity and mortality, especially in children (Sahni, 2017).

the correlation between flood vulnerability and mortality had a negative low correlation with a correlation score of -0.25 for the year 2016. In recent years disaster preparedness at the sub-national level has also become more systematic, with augmented efforts in areas which have a greater propensity of risk (Government of Bihar, 2016). This also possibly means that districts which are not high priority may be paradoxically worse affected at the times of the flood since resources are not equally distributed. This phenomenon could possibly account for the findings.

In contrast, for VBDs both pre-flood and post-flood, the morbidity data had a correlation of 0.24 and 0.11 respectively for the same year. It needs to be stressed that even in the pre-flood period, vulnerability and VBD cases may only be weakly correlated. An earlier study from India had shown that even inverse correlations are possible, depending primarily on baseline health access status (Dogra et al., 2013a, 2013b). In the post-flood scenario, the correlation could further fall. One possible reason could simply be the collapse of facilities resulting in less reporting, as has been shown elsewhere (Shortus et al., 2016). There could be several reasons for this phenomenon which need to be unravelled to understand more fully the complex linkages between climatic factors, the natural environment, biological agents and animal as well as human hosts in the societal context.

Table 3
District Ranking in Descending Order of Vulnerability.

Sr. No.	District	Score (out of 200)	Rank
1	Madhepura	131.9	1
2	Sitamarhi	128.1	2
3	Sheohar	123.9	3
4	Muzzafarpur	122.4	4
5	East Champaran	116.8	5
6	Khagaria	112.0	6
7	Vaishali	110.0	7
8	Darbangha	105.9	8
9	Katihar	102.5	9
10	Samastipur	100.3	10
11	Supaul	96.7	11
12	Madhubani	95.9	12
13	Saharsa	93.8	13
14	Bhagalpur	79.8	14
15	Begusarai	76.9	15

[3] Sensitivity map was derived using the weighted and normalized values of eight sensitivity indicators.

[4] Adaptive capacity is defined as *the degree to which adjustments in practices, processes, or structures can moderate or offset potential damage or take advantage of opportunities. Adaptive capacity* Map was derived by using the weighed and normalized values of adaptive capacity indicators defined above.

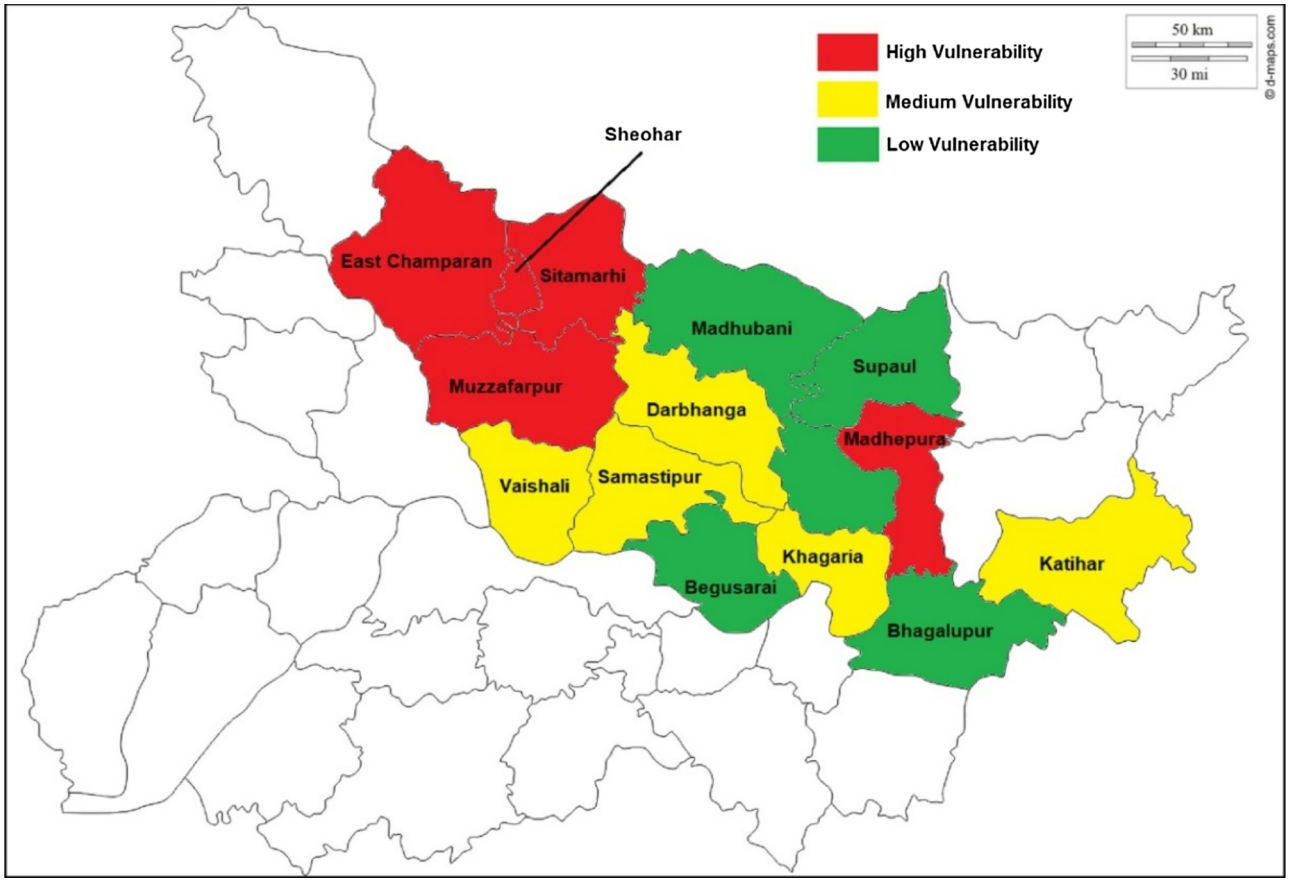


Fig. 5. Overall Climate Health Vulnerability Map of 15 Districts of Bihar.

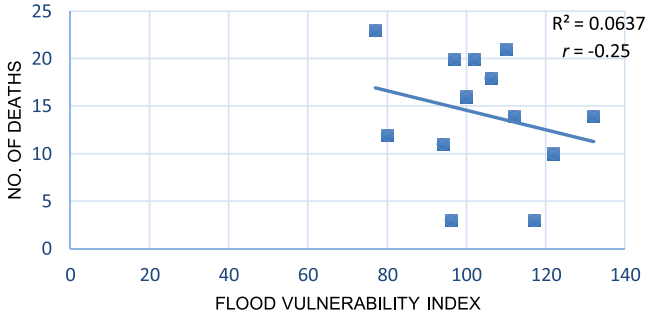


Fig. 6. Correlation Between Flood Vulnerability Index and Flood Associated Mortality in Bihar in 2016.

Table 4
Number of Flood Associated Mortality in Bihar in 2016.

Sr. No.	Districts	Vulnerability Index Score	Flood Mortality2016
1	Begusarai	77	23
2	Bhagalpur	80	12
3	Darbhanga	106	18
4	East Champaran	117	3
5	Katihar	102	20
6	Khagaria	112	14
7	Madhepura	132	14
8	Madhubani	96	3
9	Muzzafarpur	122	10
10	Saharsa	94	11
11	Samastipur	100	16
12	Supaul	97	20
13	Vaishali	110	21

5. Conclusion

The use of climate vulnerability indices in the health sector is a powerful tool that has emerged in the context of health outcomes that are climate sensitive. While planning in the health sector is predominantly determined by the prevalence of health conditions, the data sources are predominantly from government health facilities which accounts for only about 30 percent of the data at a national level in India (Tripathi et al., 2018). Hence the probability that the index rather than the prevalence will reflect the actual scenario on the ground is more likely. A detailed validation exercise (IIHMR, 2013….Assessment for Baseline Vulnerability already referenced) which accompanies the sub-national index for climate-sensitive diseases (Dogra et al., 2013a) has concluded on these lines. The other major finding relates to mortality. Disaster risk reduction in developing countries like India has been largely focussed on a response approach prior to the Hyogo framework in 2005 ("Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters", 2005). Disaster preparedness was largely assessed from the perspective of immediate impacts of a natural disaster. In this context, it is speculated that focus on these specific areas could result in increased mortality in areas less prepared to deal with the disaster. The State of Bihar however is one of the first states in India which has drawn up a long-term plan on the basis of the Sendei Framework for Disaster Risk Reduction (Bihar Disaster Reduction Roadmap, 2016). The emphasis on these plans includes vulnerability assessments such as health. However, researchers ought to construct simplified indices which can be used by program managers after due validation. They can even be used by decision makers for operational purposes in conjunction with the evolving situation on the ground. While constructing these indices, it is vital that the sources of information should be freely available so that data access

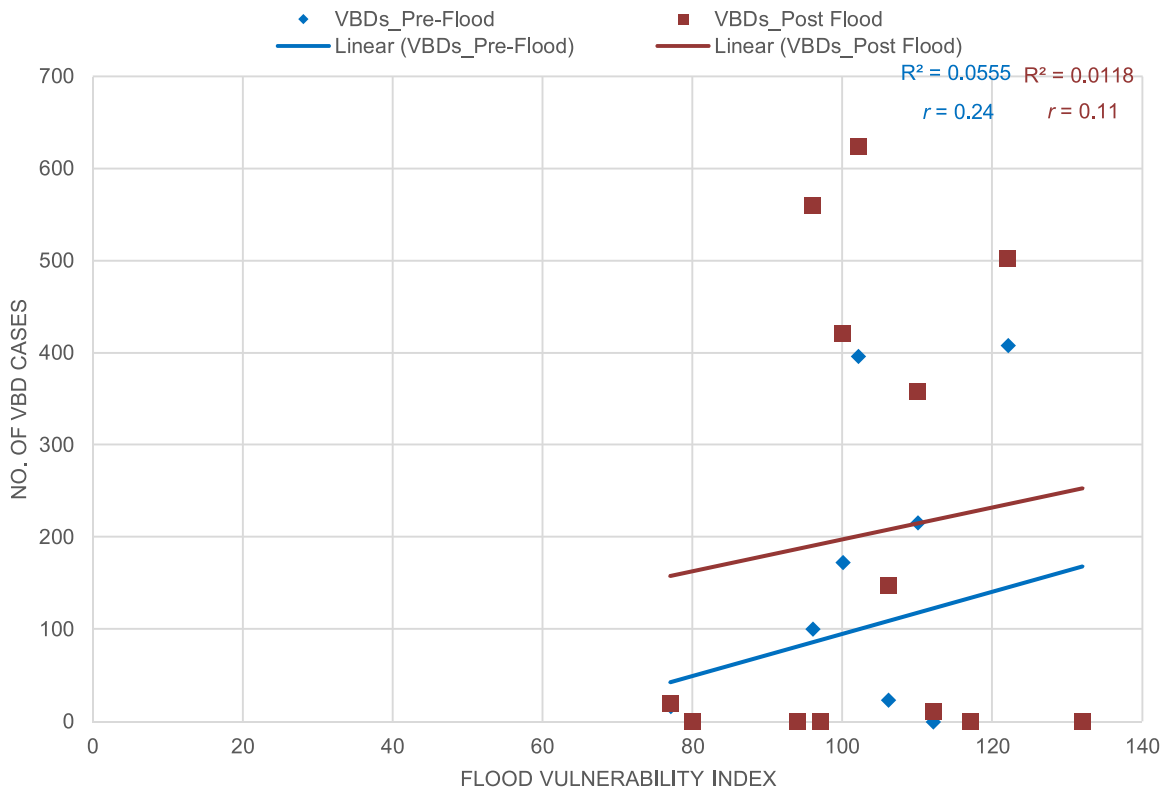


Fig. 7. Correlation Between Flood Vulnerability Index and Vector Borne Disease (VBD) Cases during Pre-Flood and Post Flood Periods in Bihar in 2016.

Table 5
No. Of VBD Cases During Pre-Flood, Flood and Post Flood Periods in Bihar in 2016.

Districts	Index Score	VBDs Pre-Flood	VBDs Post Flood
Begusarai	77	17	20
Bhagalpur	80	0	0
Darbhanga	106	24	148
East Champaran	117	0	0
Katihar	102	397	625
Khagaria	112	0	11
Madhepura	132	0	0
Madhubani	96	101	560
Muzzafarpur	122	409	503
Saharsa	94	0	0
Samastipur	100	173	421
Supaul	97	0	1
Vaishali	110	216	359

does not prove to be a barrier for anyone to work out these indices in relation to the area of work. The decision tool is thus proposed as a 'pocket tool' for the practitioner to be used along with expert guidelines and evolving inputs that may arise from the field in an operational setting.

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References

Azhar, G., Saha, S., Ganguly, P., Mavalankar, D., Madrigano, J., 2017. Heat wave vulnerability mapping for India. Int. J. Environ. Res. Public Health 14 (4). https://doi.org/10.3390/ijerph14040357.

Bao, J., Li, X., Yu, C., 2015. The construction and validation of the heat vulnerability index, a review. Int. J. Environ. Res. Public Health 12 (7), 7220–7234.

Bhunia, Gouri Sankar, Chatterjee, Nandini, Kumar, Vijay, Siddiqui, Niyamat Ali, Mandal, Rakesh, Das, Pradeep, Kesari, Shreekant., 2012. Delimitation of kala-azar risk areas in the district of Vaishali in Bihar (India) using a geo-environmental approach. Memórias do Instituto Oswaldo Cruz 107 (5), 609–620. https://doi.org/10.1590/S0074-02762012000500007.

Cardona, O.D., van Aalst, M.K., Birkmann, J., Fordham, M., McGregor, G., Perez, R., Pulwarty, R.S., Schipper, E.L.F., Sinh, B.T., 2012. Determinants of risk: exposure and vulnerability. In: Barros, T.F. Stocker, Qin, D., Dokken, D.J., Ebi, K.L., Mastrandrea, M.D., Mach, K.J., Plattner, G.-K., Allen, S.K., Tignor, M., Midgley, P.M. (Eds.), A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 65–108.

Dogra, N., Srivastava, S., 2012. Climate Change and Disease Dynamics in India. The Energy and Resources Institute (TERI).

Dogra, N., Taneja, P., Srivastava, S., Patel, S., 2013a. Pilot Tool for Assessment of Health Vulnerability to Climate Change at the Sub-National Level in India Institute of Health Management Research (WHO Collaborating Centre for District Health System Based on Primary Health Care. Retrieved from https://www.academia.edu/25298462/Pilot_Tool_for_Assessment_of_Health_Vulnerability_to_Climate_Change_at_the_Sub-National_Level_in_India_INSTITUTE_OF_HEALTH_MANAGEMENT_RESEARCH_WHO_Co llaborating_Centre_for_District_Health_System_Based_on_Primary_Health_Care.

Dogra, N., Taneja, P., Srivastava, S., Patel, S., 2013b. Assessment of Baseline Vulnerability for Climate-Sensitive Diseases at the Local Level in India Institute of Health Management Research (WHO Collaborating Centre for District Health System Based on Primary Health Care. Retrieved from https://www.academia.edu/25298463/Assessment_of_Baseline_Vulnerability_for_Climate-Sensitive_Diseases_at_the_Local_Level_in_India_INSTITUTE_OF_HEALTH_MANAGEMENT_RESEARCH_WHO_Collaborating_Centre_for_District_Health_System_Based_on_Primary _Health_Care.

Few, R., Ahern, M., Matthies, F., Kovats, S., 2004. Floods, Health and Climate Change: A Strategic Review.

Deutsche Gesel Ischaft für Internationale Zusammenarbeit (GIZ) GmbbH, 2014. Vulnerability Assessments: Climate Change Adaptation in Rural Areas of India. New Delhi: Climate Change Adaptation in Rural Areas of India (CCA RAI) and Deutsche Gesel Ischaft für Internationale Zusammenarbeit (GIZ) GmbH.

Government of Bihar, 2015. Bihar State Action Plan on Climate Change. [online] Available at: http://www.moef.gov.in/sites/default/files/Bihar- State%20Action%20Plan%20on%20Climate%20Change%20%282%29.pdf.

Government of Bihar, 2016. Roadmap for Disaster Risk Reduction 2015-2030. [online]

Available at:. http://sambal.bihar.gov.in/document/view/27.
India ratifies the Paris Agreement on Climate Change, 2016. India Ratifies the Paris Agreement on Climate Change. Retrieved January 31, 2018, from. http://envfor.nic.in/content/india-ratifies-paris-agreement-climate-change.
Khan, F.A., Salman, A., 2012. A simple human vulnerability index to climate change hazards for Pakistan. International Journal of Disaster Risk Science 3 (3), 163–176.
Malik, S.M., Awan, H., Khan, N., 2012. Mapping vulnerability to climate change and its repercussions on human health in Pakistan. Globalization Health 8, 31. https://doi.org/10.1186/1744-8603-8-31.
Ministry of Health & Family Welfare Government of India, 2016. National Action Plan for Climate Change Human Health (NAPCCHH). [online] Available at:. (Accessed 31 January 2018). http://ncdc.gov.in/writereaddata/mainlinkfile/File604.pdf.
National Sample Survey Office, 2013. Key Indicators of Drinking Water, Sanitation, Hygiene and Housing Condition in Indi (69th Round July2012 to December 2012, NSS KI (69/1.2)). Government of India, New Delhi, pp. 21–24.
O'Brien, K., Leichenko, R., Kelkar, U., Venema, H., Aandahl, G., Tompkins, H., et al., 2004. Mapping vulnerability to multiple stressors: climate change and globalization in India. Glob. Environ. Change 14 (4), 303–313. https://doi.org/10.1016/j.gloenvcha.2004.01.001.
Sahni, G., 2017. Clinico-epidemiological profile of snake bite in children - a descriptive study. Indian J. Child Health 4 (4), 503–506. Retrieved from. https://atharvapub.net/IJCH/article/view/351.
Shortus, M., Musto, J., Bugoro, H., Butafa, C., Sio, A., Joshua, C., 2016. Vector-control response in a post-flood disaster setting, Honiara, Solomon Islands, 2014. Western Pac. Surveillance Response J.: WPSAR 7 (1), 38–43. https://doi.org/10.5365/WPSAR.2015.6.3.004.
Shukla, R.S., Dogra, N., 2012. Vulnerability and adaptation. In: Dogra, N., Srivastava, S. (Eds.), Climate Change and Disease Dynamics in India. TERI Press, New Delhi, pp. 357–381.
Singh, C.S., Anima, K., Kumar, B., Gautam, E., Kumari, E.A., 2014. Environmental challenge due to climate change in Bihar, developing State of India. J. Natural Sci. Res. 4 (13), 21–28.
Tripathi, Shruti, Sharma, Rachna, Nagarajan, Shyama, 2018. MPRA paper 87067. Health Information Systems in India: Challenges and Way Forward. University Library of Munich, Germany.
WHO-WMO Joint Office for Climate and Health, 2016. Improving Health Preparedness for Extreme Heat Events in South Asia. Colombo, Sri Lanka. [online]Available at: http://www.wmo.int/pages/prog/wcp/wcsp/rcofs/sascof/health/documents/1st-South-Asia- Climate-Services-Forum-for-Health.pdf (Accessed 1 February 2018).
Wolf, T., McGregor, G., 2013. The development of a heat wave vulnerability index for London, United Kingdom. Weather Clim. Extremes 1, 59–68. https://doi.org/10.1016/j.wace.2013.07.004.
World Health Organization, 2013. Protecting Health from Climate Change: Vulnerability and Adaptation Assessment. World Health Organization.
Yusuf, A., Francisco, H., 2009. Climate Change Vulnerability Mapping for Southeast Asia.